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PLANNING OF COMBAT OPERATIONS AND TROOP CONTROL USING NETWORK TECHNIQUES

by

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Foreword

At the present time the armed forces are heavily equipped with modern weapons and technology. As a result of this, fundamental changes are taking place in the military art. Therefore the number and variety of tasks which must be dealt with both in the planning stage and in preparing the troops for combat has sharply increased. This applies both to the sphere of planning and the production of means of armed combat. The relation between various processes became very complex, and the volume of information required by staffs for commanding armies increased sharply, etc. At the same time, the time during which staffs and other commanding authorities must collect the information, analyze it and react to changes in the situation, and change or make more precise the adopted solutions or make altogether new decisions, depending on the new situation, is constantly shortened.

The existing planning and control methods, which are the heritage of time, no longer provide the necessary operativeness and quality of control.

In military science there comes into being a contradiction between the development level of the means of armed combat and the level used for their control. The development of means, forms and methods of control lags behind the development of the means of armed combat and the means of industry. Many scientists and practical workers, both in our country and abroad, are engaged in activities which are directed toward resolving the aforementioned contradiction. Their work and quest for ways to perfect control resulted in a new computational technology, various means of mechanizing control tasks, new communication means and a number of new ways for setting up controls. However the problem is far from being solved. The search continues.

The search for new and more efficient methods for the planning and control of various processes dealing with allocation of human, time, material and other resources led to the creation of a new planning and control system, which received in our country the abbreviated designation SPU[1]. This planning and control network system found a wide application in a relatively short time in

[1] SPU is network planning and control system

industry, in planning and carrying out scientific work, as well as design plans in the construction industry, and in planning the educational process in educational institutions, as well as in the domain of allocating material resources.

The wide and fast application of this new method both in our country and abroad can only be explained by its superiority over the existing, traditional planning methods.

One of the most important advantages of the network planning and control method as compared to the existing methods is its objectivity. The method makes it possible to determine objectively the minimum amount of time necessary as well as the necessary amount of material resources which must be allocated to fulfill a particular task, and thus eliminates the need for subjective judgment in the solution. The commander (leader) can make decisions on the basis of accurate and well founded calculations which are made using network graphs.

Experience has shown that the economical benefits which accrue from improved control, in the majority of cases, exceed considerably the expenditures incurred in implementing the new technology. In this respect the appearance and wide practical incorporation of the network planning and control method has tremendous possibilities. For the first time there is a real possibility of completely overhauling the organization and control of complex and large systems in all spheres of human activity, above all, in military science. The creation of a network planning and control system is considered to be one of the most outstanding achievements in the domain of control within the last 20 years.

The network planning and control method is applied in our country on a very wide scale. The application of the SPU method led to tremendous savings in time and resources in the construction of such large scale objects as the Lisichansk chemical combine, the Burshtyn State Regional Power Plant, the gigantic automated blooming mill in Chelyabinsk, and also in the construction of a subway bridge over the river Dniepr in Kiev, and in the repair of open-hearth furnaces at the "Serp i Molot" (Sickle and Hammer) metallurgical plant in Moscow, and others. This again was due to a better scientific organization of labor which was based on network graphs.

The network planning and control method can be used successfully to plan military training, the combat readiness and combat activities of the troops, and also to control armies.

The network planning and control method can also be widely applied in the construction of military objects, in the design of new weapons systems, when a whole host of complex tasks must be performed, which require for their fulfillment teams of specialists and dozens of various institutions and enterprises. Network graphs, their analysis and optimization make it possible, under these conditions, to coordinate exactly the activities of numerous collaborators in time, and also find the best ways of organizing labor in the shortest periods of time with minimum use of material resources.

Thus, for example, in the U. S. when the Polaris system was planned and executed, about 250 contractors and 6,000 sub-contractors participated, whose

activity had to be coordinated with respect to time. The network planning and control method, which is known in the U.S. as the PERT[1] system, which was applied during the construction of this rocket, contributed substantially to the successful completion of the project. The Polaris program was executed in 3 years instead of 5 as originally planned. Network techniques (in various modifications: PERT-time, PERT-cost, PERT-reliability) were applied in the U.S. armed forces during the construction of the Nike Zeus rockets and other types of complex weapons. At the present time not a single industrial firm or military project is financed by the U.S. Defense Department without a network representation of the project.

Network graphs are also used for military production in the German Federal Republic, in particular, they are applied to secure evenness in the production of the new West German "Leopard" tank. In addition to the long range applications of the SPU system in the military, we should also mention the possibility of using the system in theoretical scientific research work, when we analyze the most probable conditions of the combat situation and when we use new weapons, and especially when we make probabilistic time estimates which are necessary to fulfill particular tasks (work), or when we determine the probable attack times (march times), and when we allocate material resources, etc.

By using the SPU method we can facilitate the scientific search for the most rational ways and means of organizing combat and operations in contemporary warfare.

The available experience and the practical results obtained from applying network graphs in the army, as well as the studies dealing with this question which were carried out in the military academy of armed forces, allow us to conclude that network planning and control techniques have a great future in military science. These techniques can be successfully applied to the planning of military activities and the control of armies in all instances.

First of all these will yield great results in solving tactical problems, especially in the planning and organizational stages of military activities, and in the organization and execution of complex processes of combat, engineering, material and technical supply of the troops, in the planning and execution of mobilization matters and in alerting the armies. These methods can also be very effective in planning the combat readiness of the army and in planning the training process in the army and in educational institutions.

Finally, network graphs open up new possibilities of perfecting methods used to collect information, and speedy processing of the information on electronic computers, and further possibilities of utilizing operational codes used in the network models for the purpose of undetected control of troops.

However it should be borne in mind that all applications of the network planning and control method which were mentioned above can be implemented in the military only if officers have a good grasp of this method.

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[1]PERT is an abbreviation which stands for Program Evaluation and Review Technique.

This book is one of the first books in the military literature which is devoted to network planning and control methods. Its aim is to present the fundamental concepts and elements of network planning and control, rules for constructing network graphs, and the order in which the network parameters are calculated and optimized in the planning of military activities and their control during combat. This book also illustrates this goal by the simplest examples taken from military practice, and shows the possibility of applying the network planning and control method, as well as its significance in perfecting methods of planning and controlling military activities. The book also perfects means and ways used to organize combat readiness, armament repair, scientific research and construction work in the armed forces, to insure a high degree of combat readiness and constant combat vigilance in the army and navy.

The authors of the book have given a full exposition of the fundamentals of the network planning and control method in easily accessible form, and have shown the possibilities and principles needed to apply this method to military tasks in general and to the planning of military activities and the control of troops in particular.

The work which is presented to the reader gives a step by step exposition, which is illustrated in examples, of the methodology of constructing network graphs, their optimization, and the order in which the results of the analysis of these graphs must be used in order to improve the planning of activities and the control of troops. Therefore the book can be used for independent study of the network planning and control method, or as a handbook in the practical application of network graphs by army officers. The book was written for officers, auditors in military academies, and students in military schools.

-- Doctor of Military Science, Professor
Lieutenant General of Armored Forces
G. Zavizion

Chapter 1 General Concepts and Elements of the Network Planning and Control System: Construction of Network Graphs

1. General concepts relating to the method

Par. 1. Characteristics of the network planning and control technique

At the present time the national economy is undergoing radical changes in the direction and organization of complex processes, which involve the allocation of human, material, power and other resources. One of the most important and most widely used of the new methods used to perfect control and management is the network method. The success and the wide application of this method in practically all spheres of human activity are due first of all to its great advantages over other existing planning methods, which are based on linear graphs.

These advantages consist of the following:

1. The application of the network planning and control method on the basis of the best logically and mathematically based organization of the work brings about tremendous savings in manpower, resources and time, and makes it possible to plan and control complex projects simultaneously in a number of directions,[1] and it allows us to exclude from the domain of control those tasks which have no effect on the timely completion of the entire project; it helps us to determine bottlenecks and overcome them in due time. All this has been borne out in practice.

In military science the application of the network planning and control method enables us to gain time and achieve more effective results by basing the allocation of forces and resources which are at the disposal of the commander on precise calculations. Such planning and control are superior to the usual methods.

2. Network graphs are a convenient visual means of representing the project both as a whole and in parts. These methods make it possible to review the decisions which were made more scientifically, taking into account the situation, to make decisions for the future, and to foresee possible delays in schedules and their consequences which may affect the termination date of the project. The network planning and control system uses widely and gainfully electronic computing technology.

3. The network planning and control technique which uses network graphs to model the project makes it possible in the planning stage to reflect fully the amount of work involved in solving the problem, to show with any amount of detail the tasks which are part of the project, and to determine the relationships between these tasks, to determine the events whose completion is necessary for the fulfillment of subordinate tasks and of the project. It is also a means for efficient division of labor between the various participants in the project, and it precludes the omission of tasks which are necessary to attain the goals of the project.

4. The network planning and control technique permits a better utilization of the most qualified and prepared personnel in the planning stage, and it makes possible the practical verification of statistical data which are necessary for a realistic estimate of manpower and resources needed to fulfill the various tasks in time. In analyzing the model untapped resources are found, and ways of utilizing these are indicated, in particular the use of resources utilized for non-critical tasks, which are utilized to accelerate critical tasks, which in turn speeds up the completion of the project with smaller utilization of manpower and material resources.

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[1] By the project in the network planning and control method (SPU) we shall mean the totality of all operations which are necessary to fulfill the desired task, and which are defined in advance. This term will also be used to designate the planning of any combat activity at all levels of authority.

5. The network planning and control method makes it possible to use a simple technique for introducing changes and modifications and improving the precision of the plan, which leads to great flexibility and continuity of planning, and simplifies the processing of information and reporting, and also insures a speedy incorporation of new managerial personnel and continuous control during managerial changes on the project. Using electronic computers the network planning and control method calculates in a short period a great number of alternate ways of completing the project, from which it selects the optimal variant.

Thus the network planning and control technique makes it possible to obtain scientific answers to the most important problems which arise during the planning and coordination of many interrelated projects.

To conclude the general description of the network planning and control technique, we note that it can be applied irrespective of the size and complexity of the project. The network planning and control method is most effective in complex projects, where complex dynamic systems must be controlled and where a wide utilization of electronic computers is possible.

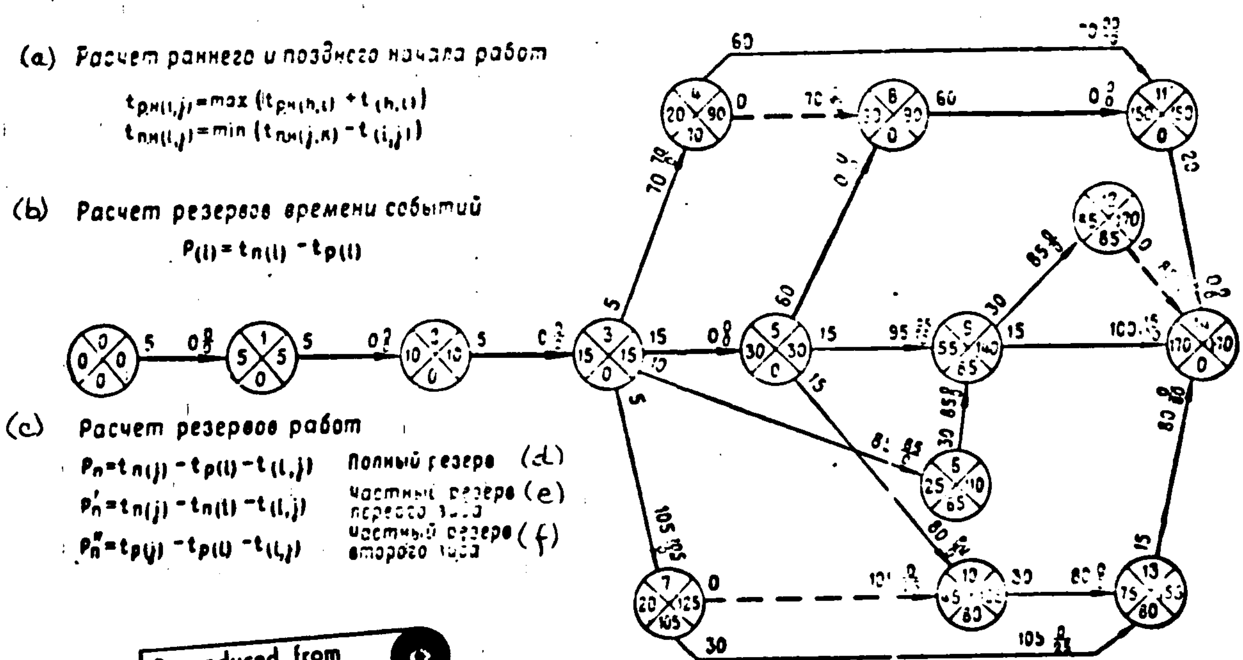

Fig. 52 Graphical calculation of the initial network graph.

[Key on following page.]

Key: (a) calculation of earliest and latest starting times
(b) calculation of slack between events
(c) calculation of slack between projects
(d) total slack
(e) partial slack of the first kind
(f) partial slack of the second kind

Thus we shall formulate in words the algorithm which was given above in formula (10´): the earliest starting time for the given project (i,j) is equal to the maximum value of the sum of the earliest starting time and the duration of the projects which preceded the given project.

If the project is preceded by only one project, then its earliest starting time is equal to the sum of the earliest starting time and the duration of the preceding project. For example, let us determine the earliest starting time of projects (1,2) and (2,3):

$$t_{\text{р.н}(1,2)} = t_{\text{р.н}(0,1)} + t_{(0,1)} = 0 + 5 = 5;$$
$$t_{\text{р.н}(2,3)} = t_{\text{р.н}(1,2)} + t_{(1,2)} = 5 + 5 = 10.$$

Key: р.н = e. st. (earliest starting time) [in all relevant formulas]

In order to determine the earliest starting time of project (1,2) using the graph, we proceed as follows: we find the event (0), and we take in the left section the starting time of the project (0,1), which is equal to zero, and add to it the time which is necessary to complete the project (0,1), which is equal to 5 minutes. The sum thus obtained is entered in the left sector of event (1). The number 5 which is placed in the left sector of event (1) shows the earliest starting time for project (1,2).

To determine $t_{e.st.(2,3)}$ we find the event (2), and we take in its left sector the starting time of project (2,3), which equals 10, and add to it the duration of the project, which is equal to 5 minutes. The sum thus obtained is put in the left sector of event (3). This time is the earliest starting time for all projects emanating from event (3), i.e., the projects (3,4), (3,5), (3,6), (3,7).

If the given project is preceded by several projects, then the earliest starting time for this project is determined as the maximum sum of the starting times and duration of all preceding projects. For example, in our example when determining the earliest starting time for project (8,11) we considered two preceding projects, namely (4,8) and (5,8). We shall determine $t_{e.st.(8,11)}$:

$$t_{\text{р.н}(8,11)} = t_{\text{р.н}(4,8)} + t_{(4,8)} = 20 + 0 = 20;$$
$$t_{\text{р.н}(8,11)} = t_{\text{р.н}(5,8)} + t_{(5,8)} = 30 + 60 = 90.$$

We take the maximum sum, i.e., $t_{e.st.(8,11)} = 90$ and enter it in the left sector of event (8). This is the earliest starting time for project (8,11).

These are the rules used to determine the earliest starting time for all projects up to the terminal event in the network.

Calculation of the latest admissible starting times

The latest starting time for a project is calculated in reverse order from that used for determining the initial starting time for the project, and is carried out in a reverse direction, from the right to the left, starting with the sink and ending in the source.

For the sink in the network the earliest starting time of succeeding projects, which, as is well known, this event does not have,is also the latest completion time for all preceding projects. Therefore the earliest starting time is transferred from the left sector of the terminal event to the right sector for this event, and the calculation proceeds in reverse order (from the right to the left) up to the initial event. In the process we write in the right sector the minimum value of the difference between the latest starting time of the succeeding project and the duration of the project. The calculation is carried out in accordance with the algorithm (formula 12).

Using our graph let us calculate the latest starting time for projects (11,14), (8,11) and (5,8):

$$t_{\text{п.н}(11,14)} = t_{\text{п.н}(14,k)} - t_{(11,14)} = 170 - 20 = 150;$$
$$t_{\text{п.н}(8,11)} = (t_{\text{п.н}(11,14)} - t_{(8,11)}) = 150 - 60 = 90.$$

Key: п.н = l. st. (latest starting time) [in all relevant formulas]

Determining these from the graph, we proceed as follows: from the number 170, which is in the right sector of the event (14), we subtract the duration for project (11,14), which is equal to 20, and obtain 150. We enter the number obtained in the right sector of event (11). We proceed similarly to obtain $t_{l.st.(8,11)}$: we subtract 60 from 150, and the result, which is equal to 90, is entered in the right sector of event (8).

If several events emanate from the event, as for example from the event (5), then we proceed as follows: we calculate the latest starting times for all projects, which emanate from the given event, and we select the minimum value from among the times obtained. In our example

$$t_{\text{п.н}(5,8)} = t_{\text{п.н}(8,11)} - t_{(5,8)} = 90 - 60 = 30;$$
$$t_{\text{п.н}(5,9)} = t_{\text{п.н}(9,12)} - t_{(5,9)} = 140 - 15 = 125;$$
$$t_{\text{п.н}(5,10)} = t_{\text{п.н}(10,13)} - t_{(5,10)} = 125 - 15 = 110.$$

The smallest value among the three quantities is the number 30. Therefore the number 30 is entered in the right sector of event (5). We note that the minimum time is selected under these conditions in order to insure that sufficient time is available to complete the longest projects without disturbing the time which was calculated for the completion of the entire process. We proceed in this way until we reach the source.

Calculation of slack

The slack for each event is determined as the diference between the latest and earliest completion times for each event:

$$P_{(i)} = t_{n(i)} - t_{p(i)}$$

Key: n = 1. (latest) [in all relevant formulas]
p = e. (earliest)

Using the graph we proceed as follows: we subtract from the quantity in the right sector of the event the quantity in the left sector of the same event. The result is entered in the lower sector of the event. For example, let us compute the slack for the events (3), (4) and (8):

$$P_{(3)} = t_{n(3)} - t_{p(3)} = 15 - 15 = 0;$$
$$P_{(4)} = t_{n(4)} - t_{p(4)} = 90 - 20 = 70;$$
$$P_{(8)} = t_{n(8)} - t_{p(8)} = 90 - 90 = 0.$$

The total slack for the project (P_t) is calculated as the difference between the latest completion time for the event and the earliest completion time of the event and the time (duration) of the project:

$$P_n = t_{n(j)} - t_{p(i)} - t_{(i,j)}$$

For example the total slack for project (9,14) is equal to

$$P_{n(9,14)} = t_{n(14)} - t_{p(9)} - t_{(9,14)} = 170 - 55 - 15 = 100.$$

The quantity obtained is entered at the end of the arrow as a fraction of the integer indicating time slack.

To determine the total slack from the graph, we proceed as follows: we subtract from the quantity in the right sector of the event (14) the quantity in the left sector of event (9) and the duration of the project:

$$P_{n(9,14)} = 170 - 55 - 15 = 100.$$

The partial slack of the first type ($P'_{t(i,j)}$) is computed as follows:

$$P'_{\text{н}(i,j)} = t_{\text{н}(j)} - t_{\text{н}(i)} - t_{(i,j)}.$$

For project (9,14) it is equal to

$$P'_{\text{н}(9,14)} = t_{з(14)} - t_{\text{н}(9)} - t_{(9,14)} = 170 - 140 - 15 = 15.$$

This slack is determined from the graph as follows: we subtract from the quantity in the right sector of event (14) the quantity in the right sector of event (9) and the duration of the project (9,14):

$$P'_{\text{н}(9,14)} = 170 - 140 - 15 = 15.$$

The result obtained is entered as the numerator in the fraction which is written above at the end of project (9,14).

Partial slack of the second kind ($P''_{t(i,j)}$) is the difference

$$P''_{\text{н}(i,j)} = t_{\text{р}(j)} - t_{\text{р}(i)} - t_{(i,j)}.$$

For project (9,14) it is equal to

$$P''_{\text{р}(9,14)} = t_{\text{р}(14)} - t_{\text{р}(9)} - t_{(9,14)} = 170 - 55 - 15 = 100.$$

From the graph this slack is determined as follows: we subtract from the quantity in the left sector of event (14) the quantity in the left sector of event (9) and the duration of the project (9,14):

$$P''_{\text{н}(9,14)} = 170 - 55 - 15 = 100.$$

We enter the number obtained as the numerator of the fraction which is written above at the end of project (9,14). The slacks for all projects are determined similarly

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